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THE

AMERICAN NATURALIST

VOL. XXXII. *August, 1898.* NO. 380.

DENTITION OF DEVONIAN PTYCTODONTIDÆ.

C. R. EASTMAN.

(*Continued from page 488.*)

PALÆOMYLUS Woodward (1891).

This genus at present includes the forms described by Newberry as *Rhynchodus frangens* (the type species), *R. crassus*, and *R. greenei*, the first two being found in the Corniferous limestone of Ohio, and the last-named in the Hamilton of Wisconsin.

The special characteristics of this genus, as recognized by Woodward,[1] are as follows: it has a relatively very broad symphysial surface, a triturating oral surface, and a single indefinite tritoral area. From Ptyctodus it is distinguished by having punctate instead of laminated tritors, and the knife-edge of Rhynchodus is replaced in this genus by a broad, uneven, grinding surface. Yet the three types approximate one another through intimate specific gradations. For example, *R. secans* presents the same general form externally as Palæomylus, and between the lower dental plates of *Palæomylus crassus* and *Ptyctodus ferox* in the adult stage there is even greater resem-

[1] *Catalogue Fossil Fishes British Museum*, Pt. ii, p. 38. 1891.

blance. Thus, while there is a general homogeneity of type in Ptyctodont dentition, transitional stages are to be observed in its different expressions.

Palæomylus frangens and *P. crassus* are sufficiently well known through Newberry's figures and descriptions. With *P. greenei*, however, the case is not so fortunate. It has not been hitherto illustrated, and the original description is very brief. As stated by Newberry, it resembles the type species (*P. frangens*), but differs in being narrower vertically, and longer and much thicker at the anterior border. No distinctions are pointed out between upper and lower dental plates.

For further information with regard to *P. greenei* we have to thank Messrs. Teller and Monroe, of Milwaukee, who have kindly supplied all the material in their possession. Of this, the most remarkable specimen — and, we may safely say, one of the most important examples of Ptyctodont dentition yet discovered — is that photographed on the accompanying plate (Fig. 48). It is rivaled only by the specimen of *Rhynchodus secans* described by Newberry, already referred to, in which four teeth were found associated in a group; and the two taken together prove beyond a doubt that the dentition consisted of a single pair of dental plates in both upper and lower jaws. The present specimen was obtained by Mr. Teller in the vicinity of Milwaukee, and is preserved in his private collection.

The teeth are imbedded in a block of limestone measuring 35 cm. in its greatest length, which coincides with the longitudinal axis of the jaws. The illustration may be most conveniently examined by turning the page sideways, with the bottom on the left, and top on the right-hand side of the observer. Oriented in this position, the two lower dental plates will be found on the right-hand side of the figure, in advance of the upper pair; the left upper dental plate is immediately above the right upper, and the left lower above the right lower. All plates have the external surface exposed, with the exception of the right upper, which is broken through obliquely. The inner side is seen near the anterior beak, but farther back it is beveled down through its entire thickness, leaving only an impression of its outer surface on the matrix. Still it shows

the anterior margin and boundary of the triturating surface very fairly; much more so than its fellow, just above, which is the poorest preserved of all.

There is really less difference in the form of the lower dental

FIG. 48. — *Palæomylus greenei* Newb. Group of four naturally associated dental plates. Teeth of the lower jaw at top, and teeth of the upper jaw at bottom of the figure. Those belonging to the left side of the mouth are on the left, and those belonging to the right side are on the right of the figure. × ½.

plates than might be inferred from the photograph, owing to perspective effects due to the curved surface of the left lower

tooth. The outlines are preserved nearly intact as far as the extreme antero-superior portion, including the beaks, where there is a slight deficiency. The fracture being an uneven one at this point, and likely to present a misleading appearance, a strip was filled in with plaster up to a level with the external surface as far as the impression of bone substance was preserved on the underlying matrix, but no further. The original boundary was probably not far distant from the dotted line shown in the figure, which has been restored from the outlines of other specimens.

The differences between upper and lower dental plates are not nearly so decided as in either Ptyctodus or Rhynchodus, yet, such as they are, leave no reasonable doubt as to the position occupied by the several teeth in the mouth. The lower dental plates have a more pronounced anterior beak, and are also deeper vertically than the upper pair; and the triturating surface is more uneven. The outline of the latter is sinuous, there being an anterior and a posterior depression, separated by a median elevation; and there are corresponding, although gentler, undulations to match in the margin of the upper dental plates. The opposing outlines coincide most nearly with one another when we make the upper beaks protrude slightly in advance of the lower, exactly as was done in the case of *Rhynchodus secans*. But there is no evidence that the beaks of the lower jaw closed outside the upper dental plates, as in Ptyctodus. On the contrary, appearances indicate that the two jaws came into direct opposition with their triturating surfaces, the same as molar teeth. There is a reverse slope to the grinding surface in both jaws; the anterior depression has a decided slope downward and inward, and the posterior depression an equally pronounced one downward and outward. The grinding surface has an average width of about 1.5 cm., and extends from the beaks as far back as the supero-posterior angle, or where it meets the perfectly straight line forming the posterior margin.

There is a peculiar appearance about the beak of the left upper dental plate which deserves notice, although it challenges explanation. Owing to its faulty state of preservation, no very satisfactory conclusions can be formed as to its nature or

relationships, and the structure is all but obliterated in the half-tone reproduction. This much, however, we are warranted in saying: the extreme tip of the beak has been broken, and the bony substance about it extensively worn away, but traces remain of a thin bony splint or prolongation, somewhat triangular in outline, attached to, and extending in front of, the beak. The ossification is apparently continuous with that of the dental plate itself, yet has not nearly the thickness of the symphysial surface, being seemingly confined to the inner face thereof. Theoretical objections certainly will not allow us to conceive of the existence of an anterior azygous tooth, nothing of the sort being known to occur in this family; nor can the structure justly be called adventitious, since one of Mr. Monroe's specimens presents a similar, yet equally baffling appearance. The only plausible conjecture we can form regarding it is that, owing to the large size of the dental plates, some other besides merely cartilaginous means was required to strengthen their union at the symphysis, and this was supplied by an ossification arising from the inner side of the dental plates, forming a sort of bony suture. Mention is made of this anomaly in the hope that future discoveries may lead to its adequate explanation.

P. predator sp. nov. (Fig. 43). — The type specimen shown in the foregoing figure (p. 483) is unique. It forms a part of the Schultze Collection belonging to the Museum of Comparative Zoology, and was found in the Devonian limestone near Gerolstein, in the Eifel District. It is of no little interest to note that the three Ptyctodont genera, although represented by vicarious species, should thus occur together in homotaxial deposits of such widely separated regions as Central Europe and the Mississippi Valley.

Unfortunately, the present solitary specimen is not very well preserved, but still enough remains to show its general form and relationships. The part exposed to view is the anterior portion, happily with the beak intact, of the right lower dental plate. The inner surface is concealed by the matrix, and, being partly abraded, it is not easy to determine the original thickness of the tooth. Evidently the triturating surface was wide, rela-

tively, since it has a present width of 1 cm. as far as it is preserved back of the beak. The anterior margin is still about 1.5 cm. in thickness, but how much more has been abraded can only be surmised. This is enough, however, to show that the form does not belong to either Ptyctodus or Rhynchodus, although it resembles the latter in contour; hence, we have no recourse but to admit it as a new species of Palæomylus. The transition to Rhynchodus, brought about through thickening of the symphysial region and development of a broad triturating surface, evidently took place through the species described above as *R. major* and *R. rostratus*.

ASSOCIATED ICHTHYODORULITES.

Rohon,[1] in his paper on Ptyctodus, mentions the occurrence in the Russian Devonian of dorsal fin-spines belonging to the so-called "Chimæroid type of ichthyodorulites," as defined by Jaekel.[2] As no other form with which the remains can be theoretically associated is present in the same horizon, Rohon suggests that both dentition and defenses may have belonged to Ptyctodus. The Russian spines are bilaterally symmetrical, triangular in section, slightly curved backward, and are orna mented with numerous small tubercles, more or less regularly arranged. The posterior face is concave, and bears a double series of small denticles.

The style of ornamentation of these spines is remarkable, and we are at once struck with the coincidence that in the Hamilton limestone of Milwaukee ichthyodorulites should be found which have a similar tuberculated ornament. Several very choice examples have been obtained by Messrs. Teller and Monroe, one of the most perfect being that reproduced in Fig. 49, the property of Mr. Teller.

This spine has a very graceful curvature, and is of comparatively large size, the length of an arc joining the extremities

[1] Rohon, J. V. Beitrag zur Kenntnis der Gattung Ptyctodus, *Verhandl. mineral. Gesellsch. St. Petersburg*, vol. xxxiii, pp. 1–16, 1895.

[2] Jaekel, O. Ueber fossile Ichthyodoruliten, *Sitzungsber. Gesellsch. naturforsch. Freunde Berlin*, No. 7, p. 123, 1890.

on the anterior margin being 20 cm. The width where it is broken off below, which is not far distant from the beginning of the exserted portion, is 5.5 cm., and the maximum thickness at this point is 5.5 mm. The spine is extremely compressed laterally, both sides being almost flat. There is no strongly marked anterior keel. The posterior face is slightly sulcated, and each side of the sulcus is set with closely approximated tubercles of somewhat larger size than those occurring elsewhere. The bottom of the sulcus is traversed by a faint longitudinal ridge, triangular in section.

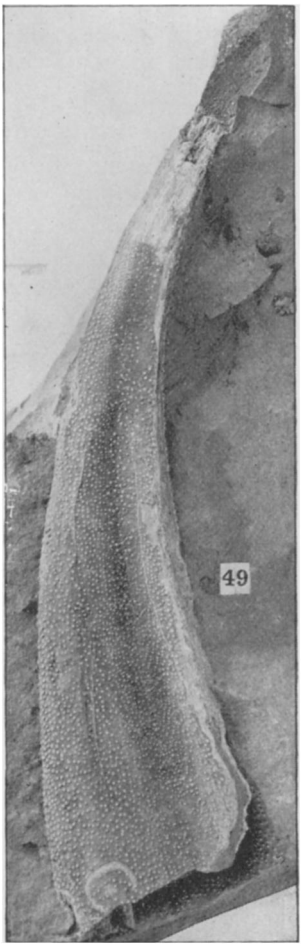

FIG. 49. — *Phlyctænacanthus telleri* sp. nov. Lateral aspect of exserted portion of spine (left face). × 3.

The individual stamp imparted to this spine by its flattened, arcuate shape is heightened by its peculiar ornamentation. The lateral faces are beset with numerous small tubercles not having a very definite arrangement, but in some specimens showing a tendency to become parallel to the anterior and posterior margins. One of Mr. Monroe's spines has the tubercles disposed more numerously along a series of parallel grooves, situated some distance apart, the whole presenting a more or less concentric appearance, and indicating successive growth stages in the development of the organ. The appearances indicate that the inserted portion tapered gradually toward the base, but this region itself has not been recognized on any of the specimens thus far examined. Most of the tubercles have been worn down smooth to their bases, or are evenly rounded on top, but a few retain traces of a fine original stellation. One or two spines, instead of

having the anterior margin uniformly curved, show a slight angulation at the region of maximum width, in that the spine tapers gradually from this point in both directions, distally and proximally.

Obviously these spines, differing as markedly as they do from the majority of Palæozoic ichthyodorulites, cannot be included under any known genus or species. We therefore propose the new genus *Phlyctænacanthus* for their reception, and have pleasure in naming the species *P. telleri* in honor of the veteran and indefatigable collector, Mr. Edgar E. Teller. Regarding their affinities, we can only suggest that they may have pertained to Palæomylus. Their large size precludes an association with either Rhynchodus or Ptyctodus; and Cladodus, the only other Elasmobranch known to occur in the Wisconsin Hamilton, was in all probability a spineless shark. On the supposition that these were the spines of *Ptyctodus ferox*, then we ought by good rights to have found similar fossils in the State Quarry fish bed, where there is such a wonderful concentration of Ptyctodus remains. But such spines as have been recovered from the Iowa locality are very different from *Phlyctænacanthus*. The latter are thus definitely excluded from all known genera occurring at Milwaukee, except Palæomylus. But as we know nothing, for instance, of the dentition with which *Heteracanthus politus* was associated, so, too, there is as much likelihood of *P. telleri* belonging to some unknown Elasmobranch genus as to Palæomylus. But as to the relative probability of one of these "genera" of Milwaukee ichthyodorulites belonging to the *Ptyctodontidæ*, the evidence of the tuberculated Russian fin-spines would go to show that *Phlyctænacanthus* is the likelier of the two to have its position established here.

(2) *Belemnacanthus giganteus* gen. et sp. nov. (Fig. 50). — This is the last form to claim our attention, and we notice it here more on account of its accompanying Ptyctodont remains in the Eifel Devonian than with the intention of suggesting possible Chimæroid affinities. In fact, we are inclined to suspect that it may have been of Ostracoderm rather than of Elasmobranch nature. But without entering into the question of its

systematic position further than this, we are content for the present with a portrayal of its general appearance, as shown in the adjoining views, supplemented by the following notes.

This unique and in many ways remarkable spine, which must be regarded as the type of a new species and genus, belongs to

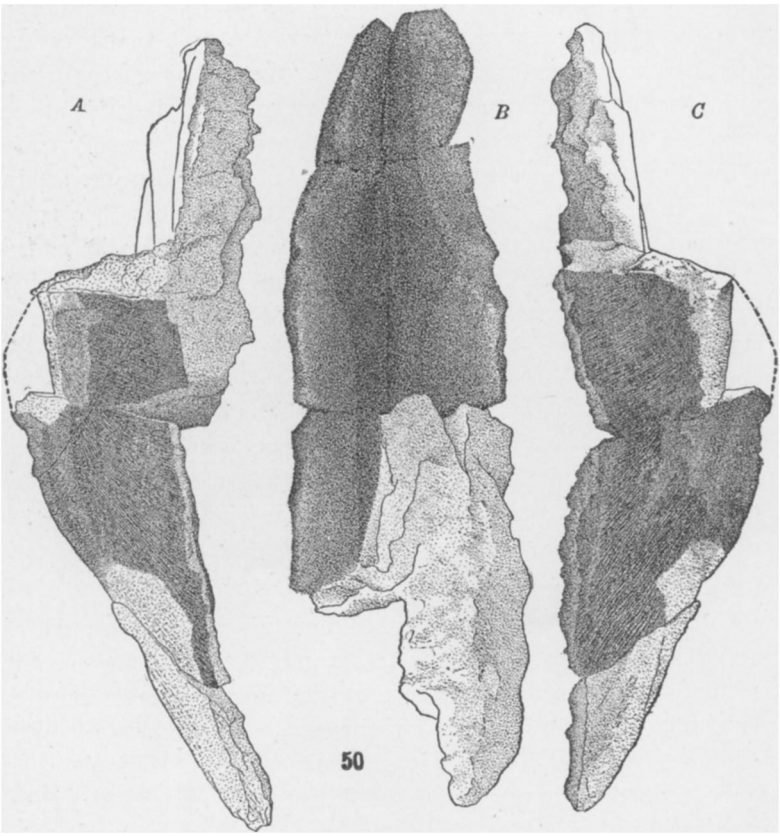

FIG. 50. — *Belemnacanthus giganteus* sp nov. *A*, *C*, lateral, and *B*, inferior aspects of spine. × ⅔.

the Schultze Collection, and was found in the Devonian, near Kerpen, in the Eifel District. It is extremely massive and even cumbersome, being solid throughout and of formidable proportions. The terminal portion of the spine is preserved for a distance of 27 cm., and the impression of it is continued for 10 cm. further, on an adherent piece of matrix. The section forms

an equilateral triangle, but the side corresponding to the posterior face in other forms is deeply excavated, the depth of the wedge-shaped cavity amounting to almost half the height of the triangle. In the view given of this side (Fig. 50, *B*), an attempt is made to show the change of slope and median groove at the bottom of the cavity. The surface of the latter is smooth throughout, and the appearances are unmistakable that it either contained soft parts or was attached to them during life. Such could hardly have been the case, however, if the spine stood erect and free from the body of the animal, but would necessarily happen were we to suppose it imbedded lengthwise in the flesh. That it actually was so imbedded appears the more probable when we consider the external aspect. Parallel markings are seen along the border on the lateral faces which apparently indicate the limits of integumentary covering; above these markings the sharp angle of the wedge protruded free as a cutwater, and probably served also as an offensive weapon; below them the bone sank beneath the skin, and was firmly secured by muscles attached to the channeled face. The latter, in the position suggested, would be *inferior* instead of posterior; the smaller, pointed end would be *posterior* instead of distal; and the larger, heavier end would be *anterior* instead of proximal or inserted.

Not only are the mechanical difficulties much lessened, of supporting free from the body an organ of such size and weight as this, according to the interpretation just outlined, but its plausibility is strengthened by the analogy of Edestus, with which it agrees in having no medullary canal. There is no doubt that the simpler types of Edestus (*E. heinrichsi*) were principally imbedded in the integument, so that only the row of denticles protruded. Bashford Dean,[1] in a very luminous paper on this genus, concludes as follows regarding the origin of the structure: "In the present case the evidence may be accepted as conclusive that a spine-like organ had its origin as a metameral structure whose basal portion lay within the integument, and traversed longitudinally a number (seven at least) of

[1] *Trans. N. Y. Acad. Sci.*, vol. xvi, p. 68, 1897. *Cf.* also *Fishes, Living and Fossil*, pp. 28–30, 1896.

body segments; and that from this condition arose a more or less typical spine shaft, thick at one end and pointed at the other, with indications that its decurved character was accompanied by a firmer insertion of the proximal end, and the evasion of a pointed tip." The stages of differentiation passed through by this genus are clearly depicted by Dr. Dean. We cannot well dissent from his view that the segmental structure observed in all species of Edestus is evidence of a primitive condition, and yet Belemnacanthus, a much earlier form, shows no trace of metamerism. Obviously, the two genera represent very different modes of origin of dermal spines. That either of them occupied a cephalic position, as suggested by Dr. Dean for Edestus, seems to the present writer improbable on account of their large size, a likelier position being somewhere along the middle of the back. Newberry's idea as to Edestus was that the spines were situated "in the position of the second dorsal fin on the back or tail of a Plagiostome fish."

The light-colored area at the posterior or pointed end of Belemnacanthus (Fig. 50, *A*, *C*) has been injured somewhat by atmospheric erosion, but still permits the course of the vascular canals to be seen. These run essentially parallel to the ornamental markings on the lateral faces, and prove that growth took place by additions to the posterior end. The markings referred to are in the nature of superficial pittings and furrows, the latter being sometimes continuous and bifurcating, or again short and interrupted. The dotted outline along the crest indicates the position of a thin piece of bone that, having been accidentally broken off from here, was used for sectioning. Nothing very conclusive was gained by this operation, however. The projecting portion of matrix at the top of Fig. 50, *A*, *C*, preserves an impression of the base of the spine as far as it extends. The lower margin being evenly arched throughout its extent of 37 cm., and the summit also as far as it is preserved, we note in this another point of resemblance to Edestus. In conclusion, it may be worth while to record that the largest Arthrodires yet obtained from the Eifel Devonian are *Aspidichthys ingens* v. Koenen; *Anomalichthys scaber* v. Koenen; and *Dinichthys eifeliensis* Kayser; and the largest Elasmobranch the

above-described *Palæomylus predator*. None of these are at all comparable, however, with the gigantic proportions indicated by Belemnacanthus.

ON THE RELATIONS OF THE DEVONIAN FISH-FAUNA OF MILWAUKEE.

Although fish remains are not at all plentiful near Milwaukee, yet the working of the Hydraulic Cement quarries within five miles of the city has enabled collectors to bring together a considerable variety of chordate fossils during the course of time. Only three forms from this locality were known to Newberry when writing his Monograph in 1889. These were *Rhynchodus excavatus*, *Palæomylus greenei*, and *Heteracanthus politus*. Besides the forms made known in the present paper, *Dinichthys pustulosus* was described last year from material that has long been preserved in the Museum of Comparative Zoology. In addition, a few unrecorded and several new species have been obtained by Messrs. Teller, Monroe, and Slocum, making a total representation of at least fifteen species. Among the new species are a tuberculated Titanichthys, plates of Sphenophorus which prove this little-known genus to be an Arthrodire, teeth of Cladodus with curved crown and strong lateral denticles, beautiful large scales of Holoptychius, and a number of dermal ossifications that are undoubtedly of Chimæroid nature. One of the latter bears some resemblance to Myriacanthus. Some detached Ptyctodus tritors are indistinguishable from *P. calceolus*, and one of the Heteracanthus spines seems to be identical with *H. uddeni* Lindahl.

Without question, the most interesting of all these remains, scientifically, is *Dinichthys pustulosus*. The meager material upon which it was founded is now increased by several more or less perfect crania, half a dozen dorso-median plates, the antero- and postero-dorso-laterals, the clavicular (which has the flat outer surface tuberculated), and one of the shear teeth. Unfortunately, the mandibles have thus far escaped detection. The writer's prediction, based upon the peculiar ornamentation of this species, that it would one day prove to be a very primitive

species of Dinichthys, is abundantly verified by the new discoveries, since a more ideal connecting link between Coccosteus and Dinichthys could hardly be imagined. Intermediate characters are most strikingly exemplified by the cranial sutures, sensory canals, and form of the dorso-median plate. A more detailed account of its organization will be presented later. Our purpose now is to call attention chiefly to the facts of its distribution, along with the accompanying Ptyctodont remains.

In the first place, we note that *Dinichthys pustulosus*, *Heteracanthus uddeni*, and probably *Ptyctodus calceolus* all occur together in the Hamilton of Milwaukee, the State Quarry fish-bed of Johnson County, Iowa, and in the vicinity of Buffalo, Iowa, and Rock Island, Illinois. The Rock Island section has lately been worked up in considerable detail by J. A. Udden,[1] who distinguishes thirteen different beds. Beds Nos. 2, 3, and 4, of his published section, contain the assemblage of fish remains now under discussion, but Ptyctodus also extends upward into Nos. 5 and 9. No. 2 corresponds to the Gyroceras beds of Calvin and Barris, No. 3 to the lower part of the Cedar Valley limestone, and No. 4 to its upper part. Professor Udden has traced out the subdivisions of the fish-bearing beds with great care, and has very kindly submitted the following table for publication at the writer's request, by means of which any one can readily orient himself when collecting in the field.

DESCRIPTIVE TABLE OF PART OF THE SECTION OF DEVONIAN ROCKS EXPOSED NEAR ROCK ISLAND, ILLINOIS.

No. 4 (= UPPER PART OF CEDAR VALLEY LIMESTONE).	(*b*) A slightly argillaceous bluish limestone filled with fragments of Crinoid stems, locally changing into a white compact limestone, from 6 to 10 feet in thickness. *Megistocrinus latus* Hall and *Striatopora rugosa* Hall almost invariably occur near the base of this division. Transition to the coral-bearing beds above always abrupt and conspicuous. (*a*) An argillaceous bluish limestone weathering to a dirty yellow. Thickness from 15 to perhaps over 20 feet. Principal fossils are: *Aulopora* sp.; *Monticulipora* sp.; *Streptelasma rectum* Hall; *Atrypa aspera* Schloth.; *Spirifer pennatus* Hall; *S. asper* Hall; *Chonetes pusillum* Hall; *Strophodonta demissa* Conrad; *S. perplana* Conrad; *Orthis iowensis* Hall; *Cyrtina hamiltonensis* Hall; *Goniatites* sp.; *Phacops* sp.; *Heteracanthus uddeni* Lindahl; *Dinichthys* fragments.

[1] *Journ. Cincinnati Soc. Nat. Hist.*, vol. xix, No. 3, pp. 93–95, 1897.

No. 3 (= LOWER PART OF CEDAR VALLEY LIMESTONE).

(*f*) A layer of calcareous shale or clay, 6 inches thick, containing mostly Brachiopods and Bryozoa.

(*e*) A bed of olive-colored limestone, 2 feet in thickness, rich in fossils, especially Brachiopods, such as *Spirifer pennatus* H.; *S. asper* H.; *Chonetes pusillum* H.; *Strophodonta demissa* Conr.; *S. perplana* Conr.; *Discina* sp. A branching *Monticulipora* generally present about the middle of this bed.

(*d*) A layer of greenish calcareous shale, 6 inches thick, with fossils like those in the ledge below. *Strophodonta perplana* Conr. more abundant.

(*c*) A ledge of limestone, about 16 inches in thickness, of a dull dove color, fine and massive below, almost a shell breccia above. Rich in Brachiopods, such as *Spirifer asper* H.; *S. pennatus* H.; *Atrypa aspera* S.; *Orthis iowensis* H.; *O. vanuxemi* H.; *O. suborbicularis* H.; *Strophodonta demissa* Conr.; *S. perplana* Conr.; *S. nacrea* H.; and *Chonetes pusillum* H.

(*b*) A layer of greenish calcareous shale, 6 inches in thickness, containing mostly Brachiopods like those above.

(*a*) A bed of limestone, 2 feet thick, consisting below of a gray compact rock not dissimilar from No. 2 (*d*); above, it becomes slightly laminated and more fossiliferous. Brachiopods predominate above, corals below. A seam in which fossils are etched and partially dissolved separates this bed from the ledge beneath.

No. 2 (= GYROCERAS BEDS OF CALVIN).

(*d*) A ledge of limestone, about 2 feet thick, gray, compact, and strong, the upper part often marked with yellowish or brownish blotches. Principal fossils are: *Stromatopora* sp.; *Favosites alpenensis* Winch.; *F. placenta* Rom.; *Acervularia davidsoni* E. and H.; *Phillipsastræa gigas* Owen; *Crepidophyllum archiaci* Bill.; *Cystiphyllum americanum* E. and H.; *C. sulcatum* Bill.; *Atrypa aspera* S.; and *Spirifer*. Also *Dinichthys pustulosus* Eastm. and *Ptyctodus calceolus* N. and W.

(*c*) A thin layer of limestone, only a few inches in thickness, not always separated from the next above; frequently containing thin seams of clay. *Phillipsastræa* and *Stromatopora* are quite abundant.

(*b*) A ledge of gray compact limestone, about 3 feet thick, invariably containing *Phillipsastræa* and *Crepidophyllum* near the top. Besides having most of the fossils found in the ledge below, it contains: *Chonophyllum* sp.; two or three species of *Cystiphyllum*; one of *Alveolites* of fine, dense structure and spheroidal form; several species of Gastropods and Trilobites; *Phragmoceras*; and *Ptyctodus* tritors.

(*a*) A ledge about 2 feet thick, consisting of a strong, finely granular, and compact gray limestone, with a slight tinge of dusky straw color, occasionally divided by two seams near the middle. Principal fossils are: several species of *Favosites*, *Acervularia*, and other Cyathophylloids; *Stromatopora*; *Spirifer subundifera* M. and W.; *Atrypa reticularis* L. (often with well-preserved spiralia).

From the above it will be seen that the pisciferous beds near Rock Island lie within the equivalent of the Cedar Valley

limestone, with Ptyctodus extending both above and below this level. The State Quarry fish-bed is held by Professor Calvin [1] to represent a later horizon than the Cedar Valley limestone, its anomalous relations leading him to the conclusion "that it was deposited unconformably upon the Cedar Valley limestone after the lapse of a considerable erosion period." The evidence of invertebrate remains indicates that "the relations of the State Quarry limestone are with the Upper and not with the Middle Devonian, as is the case with the Cedar Valley beds." Certainly the vertebrate fauna occurring here is unparalleled elsewhere in the Devonian, but in the assemblage we note the same species of Ptyctodus and Dinichthys as are found at Milwaukee and Rock Island, and probably also Heteracanthus.

Where, now, shall the Milwaukee horizon be placed in the series? The strata here are divisible into two formations, the lowermost being the fish-bearing cement rock, and the uppermost a soft shale apparently destitute of vertebrate remains. Dr. Stuart Weller,[2] who has made a study of the invertebrates, finds that those from the lower formation are apparently most closely related to the typical eastern Hamilton fauna, as represented in New York state, although there are a few forms which seem to represent the Iowa faunas. The upper formation has an abundant and well-preserved fauna, very different from that below. It is not the New York Hamilton fauna, but appears to be intimately related to some of the Iowa Devonian assemblages. With these generalizations vertebrate evidence stands in substantial agreement. Through Rhynchodus, Palæomylus, and primitive Dinichthyids, the hydraulic limestone fauna is related to that of the eastern province, dating back even to the Corniferous of Ohio. The Chimæroids give it a stamp of antiquity, suggesting that a westward migration took place during the early part of the Devonian as far as Wisconsin, but not crossing the Mississippi Valley until the Middle Devonian. The Milwaukee beds show the first traces of encroachment from the east, the Rock Island locality a somewhat later, and the State Quarry limestone the last of all, with its horde of Upper

[1] *Ann. Rep. Iowa Geol. Survey*, vol. vii, pp. 78, 79, 1897.

[2] *Ann. N. Y. Acad. Sci.*, vol. xi, p. 117, 1898.

Devonian lung-fishes. By this time the gigantic Chimæroids (Palæomylus, *Ptyctodus ferox*, Phlyctænacanthus, etc.) had disappeared; the ubiquitous *Ptyctodus calceolus*, it is true, persisted for a while through sheer force of numbers, but after the State Quarry epoch is met with no more. Cladodonts seem to have had a continuous existence throughout this period, appearing first in the Lower Devonian of Campbellton, New Brunswick (Protodus, Doliodus, etc.), but they do not appear to have migrated west of Wisconsin until the Carboniferous. They did not fairly enjoy their ascendency until after the lung-fishes had suffered a decline.